Cost and Performance Enhancements for a PEM Fuel Cell System

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Objectives

- Develop an optimum turbocompressor configuration by working with fuel cell system manufacturers and continuing the work currently performed
- Reduce turbocompressor/motor controller costs while increasing design flexibility
- Develop and integrate the turbocompressor/motor controller into a fuel cell system

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year R,D&D Plan:

- A. Compressors/Expanders

Approach

- Use automotive and aerospace turbomachinery technology for low cost and low weight/volume
- Build upon previous turbocompressor experience
- Use VNT® (variable nozzle turbine) inlet geometry for improved performance across the desired flow range
- Use a mixed flow type compressor for improved low flow performance
- Use contamination/oil-free and zero maintenance compliant foil air bearings
- Use a modular approach to improve design flexibility
- Use a high efficiency, low cost two pole motor
- Use a low-cost variable speed motor-controller topology design that does not require sensors

Accomplishments

- Requirements established from various developers' inputs
- Analysis and design of the reduced cost and enhanced performance turbocompressor, motor and motor controller are underway

Future Directions

- Complete testing of the turbocompressor VNT® variable nozzle turbine
- Complete analysis, design, and fabrication of a reduced cost and enhanced performance turbocompressor

- Complete analysis, design, and fabrication of a reduced cost and enhanced performance motor
- Complete analysis, design, and fabrication of a reduced cost and enhanced performance motor controller with no sensor requirements

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Introduction

The objective of this work is to develop an air management system to pressurize an automotive fuel cell system. The turbocompressor is a motor-driven compressor/expander that pressurizes the fuel cell system and recovers subsequent energy from the high-pressure exhaust streams. Under contract by the U.S. Department of Energy, Honeywell designed and developed the motor driven compressor/expander and evaluated performance, weight and cost projection data. As compared to positive displacement technology, the turbocompressor approach offers potential for high efficiency and low cost in a compact and lightweight package.

Approach

The turbocompressor design currently underway for the 'Cost and Performance Enhancements for a PEM Fuel Cell Turbocompressor' project consists of a mixed flow compressor impeller, a VNT® variable nozzle turbine, and a motor magnet rotor incorporated onto a common shaft operating up to a speed of 110 krpm on compliant foil air bearings. A motor controller drives and controls the motor, which is capable of driving the turbocompressor to the maximum design speed. The air bearings are lubrication free in addition to being lightweight, compact, and self-sustaining; no pressurized air is required for operation.

The turbocompressor will operate by drawing in ambient air, compressing it, and then delivering it to the fuel cell stack, fuel processor if available, and to the motor and bearing cavities for cooling. The exhaust streams will then be expanded through the turbine to aid in the overall turbocompressor/fuel cell system efficiency. The design will be modular to enhance system developer flexibility. The motor, which will be of the two pole toothed type, and the motor controller, which will incorporate controls that do not require separate sensors for operation, will be conducive to low cost and improved packaging.

Both the mixed flow compressor impeller and the VNT® variable nozzle turbine improve system performance by improving the flow, pressure ratio and power characteristics of the turbocompressor over the flow range. The mixed flow compressor impeller design (coming from various aerospace applications) and the VNT® variable nozzle turbine (from the Garrett Engine Boosting Systems automotive turbocharging division) make the design low cost.

Results

The existing turbocompressor with a mixed flow compressor and a VNT® variable nozzle turbine, shown in Figures 1, 2 and 3, is scheduled to be tested in late 2003. The mixed flow compressor showed improved low flow performance with an improved surge line; however, the VNT® variable nozzle turbine, which would have further improved

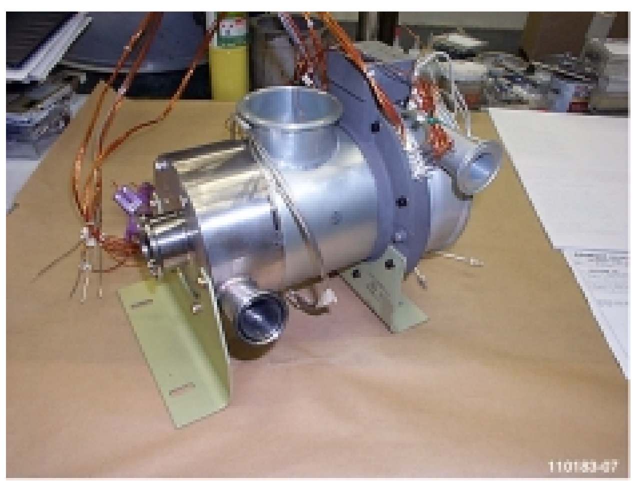

Figure 1. Honeywell Fuel Cell Turbocompressor with Mixed Flow Compressor and VNT® Variable Nozzle Turbine

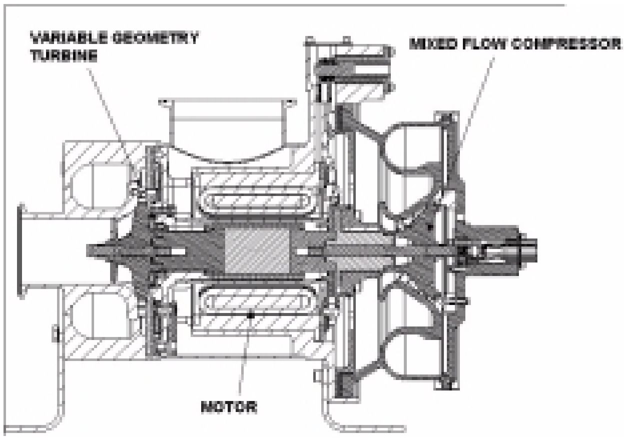

Figure 2. Cross Section of Honeywell Fuel Cell Turbocompressor with Mixed Flow Compressor and VNT® Variable Nozzle Turbine

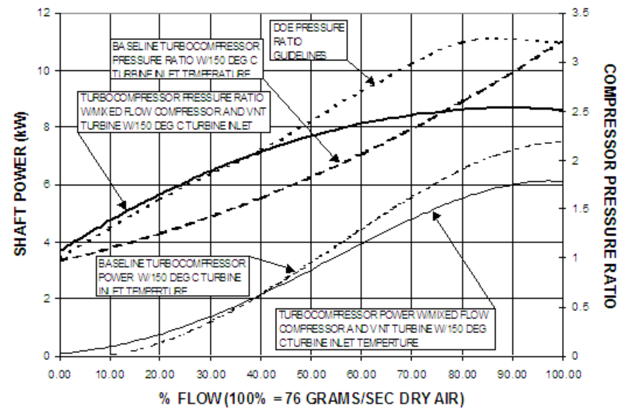

Figure 4. Turbocompressor Shaft Power/Compressor Outlet Pressure Ratio vs. Percent Flow (Baseline curves are based on actual data; mixed flow and VNT® curves are predicted.)

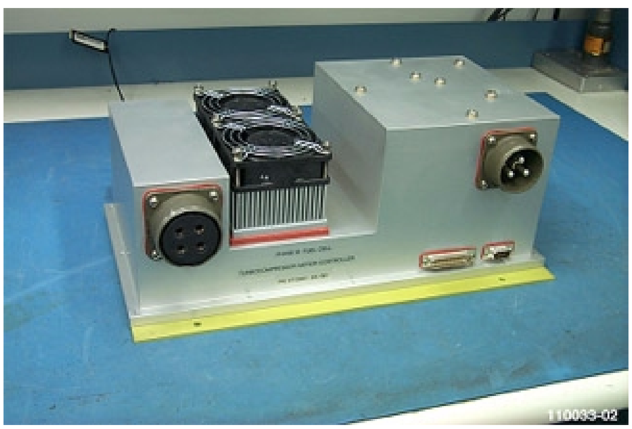

Figure 3. Fuel Cell Turbocompressor Motor Controller

Table 1. Fuel Cell Turbocompressor Physical Parameters

DOE Parameters	DOE Targets	Honeywell Turbocompressor
Weight	3 kg total (w/o heat exchangers)	Turbocompressor and motor: 6.0 kgController: 5.0 kg
Volume	4 L total (w/o heat exchangers)	Turbocompressor and motor: 4.0 LController: 6.0 L

performance and, consequently, lowered overall power consumption, was not tested due to project constraints. The test data noted above will be used in the 'Cost and Performance Enhancements for PEM Fuel Cell Turbocompressor' project. Predicted and tested performance of the turbocompressor and motor/controller with the mixed flow compressor test results are presented in Figure 4.

After working with the various system developers and the DOE, a set of specifications was completed for the 'Cost and Performance Enhancements for a PEM Fuel Cell Turbocompressor' project. Work on the reduced cost and enhanced performance turbocompressor, motor and motor controller layout and analysis is underway with preliminary weight and volume shown in Table 1. The design is scheduled to be completed in 2003.

Conclusions

- The turbocompressor concept using self-sustaining compliant foil air bearings has demonstrated low power consumption and good pressure ratio at low flow rates in a compact, lightweight package.
- Testing and subsequent analysis has predicted positive effects of the mixed flow compressor to the fuel cell system performance, with improved efficiency and pressure ratio across the flow range.
- Analysis has predicted positive effects of the VNT® variable turbine nozzle across the flow and temperature range, with efficient recovery of energy from the fuel cell exhaust.

- Working with the various fuel cell system developers and the DOE, a complete set of specifications has been generated.
- The turbocompressor, motor and motor controller layout and analysis are underway.

FY 2003 Publications/Presentations

1. Air Management Systems, SAE TOPTEC; April 9, 2003
2. Fuel Cell Turbocompressor, DOE Hydrogen, Fuel Cells and Infrastructure Technologies Program; May 22, 2003